Restoration of shoulder motion using single- versus dual-nerve repair in obstetrical brachial plexus injury

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OBJECTIVE The purpose of this study was to compare shoulder abduction and external rotation (ER) after single-nerve repair of the upper trunk alone versus dual-nerve repair of both the upper trunk and the suprascapular nerve.

METHODS A retrospective chart review of a single surgeon's experience repairing obstetrical brachial plexus injuries between June 1995 and June 2015 was performed. Eight patients underwent repair of the upper trunk alone, and 10 patients underwent repair of the upper trunk and the suprascapular nerve. Shoulder abduction and ER ranges of motion (ROMs) (in degrees) were recorded preoperatively and postoperatively. Postoperative ROM and the difference in ROM gained after surgery were compared by independent t-test analysis.

RESULTS The mean follow-up time was 161.4 weeks (range 62–514 weeks, SD 124.0 weeks). The mean patient age at the time of surgery was 31.3 weeks (range 19.9–47.0 weeks, SD 6.9 weeks). The mean postoperative shoulder abduction ROMs were 145.0° (range 85°–180°, SD 39.4°) after single-nerve repair and 134.0° (range 90°–180°, SD 30.3°) after dual-nerve repair ($p = 0.51$). The mean postoperative shoulder ER ROMs were 67.5° (range 10°–95°, SD 28.8°) after single-nerve repair and 72.0° (range 10°–95°, SD 31.3°) after dual-nerve repair ($p = 0.76$).

CONCLUSIONS The authors found no difference in shoulder abduction and ER between patients who underwent single-nerve repair of the upper trunk alone and those who underwent dual-nerve repair of both the upper trunk and the suprascapular nerve.

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KEY WORDS obstetrical brachial plexus injury; Erb's palsy; neurotization; nerve transfer; nerve graft; peripheral nerve

It is widely accepted that abduction and external rotation (ER) are crucial for shoulder function restoration after obstetrical brachial plexus injuries (OBPIs). Various approaches and techniques for restoring shoulder function have been described in the literature. Adequate results from many types of repairs have been reported in the literature. Common donors for nerve transfer include the spinal accessory nerve, intercostal nerves, and long head of the triceps motor branch.^{1,8–11,17} Common recipients include, but are not limited to, the suprascapular nerve, the upper trunk, and the axillary nerve.^{15,16,19} Double- and triple-nerve transfers also have been widely used with various combinations of recipients and donors with

or without nerve grafts.^{2–4,6} In this study, we investigated the results of shoulder abduction and ER in patients after single-nerve repair of the upper trunk versus those in patients after dual-nerve repair of the upper trunk and the suprascapular nerve.

Methods

After obtaining approval from the McGill University Health Center Research Ethics Board, we reviewed the cases of patients with OBPIs managed by the senior author (T.Z.) between June 1995 and June 2015. Patients in the single-nerve-repair group (group 1) were included if

ABBREVIATIONS ER = external rotation; OBPI = obstetrical brachial plexus injury; ROM = range of motion.

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TABLE 1. Patient characteristic comparison

Characteristic	Single-Nerve Repair	Dual-Nerve Repair	p Value
Total no. of patients	8	10	
Mean follow-up time in wks (range, SD)	144.8 (62.0–514.0, 155.9)	174.6 (89.0–384.0, 98.5)	0.63
Sex, male (%)	62.5	30.0	0.18
Mean gestational age in wks (range, SD)	39.4 (38.7–41.0, 0.77)	39.9 (38.9–40.9, 0.76)	0.24
Mean birth weight in g (range, SD)	4403.0 (3570.0–5060.0, 470.8)	4301.5 (3429.9–5669.6, 565.0)	0.69
Maternal diabetes (%)	25.0	10.0	0.41
Assisted delivery (%)	87.5	80.0	0.68
Shoulder dystocia (%)	75.0	90.0	0.41
Clavicular fracture (%)	0	10.0	0.37
Humeral fracture (%)	0	0	
Asphyxia (%)	0	20.0	0.19

they underwent interpositional nerve grafting of the upper trunk. All interpositional nerve grafts were performed with a sural nerve donor. Patients were included in the dual-nerve-repair group (group 2) if they underwent additional neurotization of the suprascapular nerve with the spinal accessory nerve. Patients were included if their injury was classified as Narakas^{12,13} grade 1 (C5–6 injury) or 2 (C5–7 injury). Each patient underwent primary brachial plexus nerve reconstruction. Patients were excluded from the study if their injury included lower trunk involvement (C8–T1), they were followed up for < 12 months, or they underwent one or more secondary procedures.

The surgeon's decision for considering surgery for a patient with OBPI is based on the following principles: 1) no recovery of biceps function at 3 months of age, 2) inadequate recovery of biceps function at 5–9 months of age, or 3) Horner syndrome in association with total palsy or involvement of C8–T1 at 3 months of age. The general goals of surgery are to maximize shoulder abduction and ER and to maximize elbow flexion if there is significant preoperative deficit. Each patient in this study underwent a supraclavicular exploration of the brachial plexus and, if necessary, infraclavicular exploration via an anterior approach. Target distal nerves for shoulder function were the posterior division of the upper trunk (group 1) with or without the addition of the suprascapular nerve (group 2). All nerve repairs were performed with an end-to-side coaptation (nerve grafts and nerve transfers) according to surgeon preference. The window for all end-to-side coaptations involved both an epineural and a perineural partial transection of nerve fibers ("lesional window"). Distal coaptation of sural nerve grafts to the posterior division of the upper trunk was performed for abduction of the shoulder (axillary nerve). Proximal coaptations to the chosen viable nerve root (C-5, C-6, or C-7) were performed. The distal coaptation site of the spinal accessory nerve transfer was the suprascapular nerve. The site of distal coaptations for the nerve grafts and nerve transfers was chosen based on the maximal response from direct intraoperative nerve stimulation (the point of maximal muscular contraction). All coaptations were performed under a microscope using a combination of 10-0 Ethilon sutures and Tisseel fibrin sealant.

All patients were followed in a multidisciplinary OBPI clinic. Data were collected from electronic and paper medical records by 2 independent reviewers. Abduction range of motion (ROM) was measured (in degrees) against gravity. The hand on the abdomen was considered 0 degrees when measuring ER ROM with gravity eliminated. Preoperative and postoperative shoulder abduction and ER ROMs were measured by the occupational therapist and the physical therapist in the OBPI clinic. In the event of a discrepancy between measurements made by the occupational and physical therapists, the larger value was kept. Means and frequencies were calculated for continuous variables and categorical data, respectively. Postoperative ROM and the difference in ROM gained (in degrees) after surgery were compared by independent t-test analysis. Statistical significance was set at a p value of 0.05. All analyses were carried out using the statistical program IBM SPSS (IBM Corp.).

Results

A total of 18 patients were included in this study. The mean follow-up time was 161.4 weeks (range 62–514 weeks, SD 124.0 weeks). The mean patient age at the time of surgery was 31.3 weeks (range 19.9–47.0 weeks, SD 6.9 weeks). The mean birth weight was 4347 g (range 3429–5669 g, SD 513 g), and the mean gestational age was 39.7 weeks (range 38.7–41.0 weeks, SD 0.78 weeks). Patient characteristics of both groups are compared in Table 1. The mean postoperative shoulder abduction ROMs were 145.0° (range 85°–180°, SD 39.4°) after single-nerve repair and 134.0° (range 90°–180°, SD 30.3°) after dual-nerve repair. The mean postoperative abduction ROMs gained were 83.2° (range 15°–180°, SD 63.7°) after single-nerve repair and 89.0° (range 20°–150°, SD 38.9°) after dual-nerve repair. The mean postoperative shoulder ER ROMs were 67.5° (range 10°–95°, SD 28.8°) after single-nerve repair and 72.0° (range 10°–95°, SD 31.3°) after dual-nerve repair. The mean postoperative ER ROMs gained were 53.8° (range 0°–95°, SD 34.3°) after single-nerve repair and 69.0° (range 10°–95°, SD 29.7°) after dual-nerve repair. We found no statistical difference in postoperative shoulder abduction and ER ROMs between the single- and

TABLE 2. Data summary for patients who underwent single-nerve repair (upper trunk alone)

Pt No.	Sex	Age at Op (wks)	Injury	Repair	Postop ROMs (°)		Changes in ROM (°)*	
					Abduction	ER	Abduction	ER
1	M	19.9	C5–6	C6–UT	180	90	180	90
2	M	40.7	C5–7	C6–UT	95	45	15	45
3	M	28.9	C5–6	C7–UT	180	10	180	10
4	M	29.7	C5–7	C7–UT	180	90	70	60
5	F	32.6	C5–7	C7–UT	160	80	70	0
6	M	36.3	C5–7	C7–UT	120	70	30	70
7	F	39.6	C5–7	X1–UT, C5–UT, C7–UT	160	95	80	95
8	F	47.0	C5–7	C5–UT, C7–UT	85	60	40	60

Pt = patient; UT = upper trunk; X1 = spinal accessory nerve.

* ROM gained after surgery (postoperative minus preoperative ROM).

dual-nerve-repair groups ($p = 0.51$ and 0.76 , respectively). We also found no difference between the single- and dual-nerve-repair groups for shoulder abduction and ER ROMs gained ($p = 0.81$ and 0.33 , respectively). Data summaries for the patients who underwent single-nerve repair and those who underwent dual-nerve repair are provided in Tables 2 and 3, respectively.

Discussion

The purpose of this study was to compare restoration of shoulder function after single-nerve repair versus that after dual-nerve repair. Comparing donor nerves was not the purpose of this study. Increasing the number of donor nerves used in such repair procedures has been reported to improve shoulder function in the adult population. Cardenas-Mejia et al.³ reported significantly improved shoulder abduction in patients after double- or triple-nerve transfers when compared with that in patients after single-nerve transfer. After pooling data from multiple procedures together, they reported mean shoulder abduction ROMs of 160° after triple-nerve transfer, 85° after double-nerve transfer, and 65° after single-nerve transfer. Garg et al.⁷

performed a systematic review of the literature and reported improved shoulder abduction and ER in patients after dual-nerve transfer (2 donors and 2 recipients) over that in patients after single-nerve transfer (1 recipient) to treat traumatic brachial plexus injury.

Comparing nerve grafting and neurotization was also not the purpose of this study. Conflicting evidence exists with regard to superiority of one method over the other for shoulder function restoration in both the adult and pediatric populations. In a systematic review of traumatic brachial plexus injuries, Garg et al.⁷ found no significant difference in shoulder abduction of grade M4 or greater (according to the British Medical Research Council grading system) when comparing neurotization versus nerve grafting to the axillary nerve. Another study by Baltzer et al.¹ also found no difference in shoulder abduction ROMs between adults who underwent nerve transfer and those who underwent nerve grafting to the axillary nerve. Terzis and Kostas¹⁷ found significantly greater shoulder abduction ROMs after direct transfer of the spinal accessory nerve to the suprascapular nerve compared with that after a nerve graft interposed between the 2 nerves (57.7° vs 44.5° , respectively, $p < 0.05$). In a large comparative

TABLE 3. Data summary for patients who underwent dual-nerve repair (upper trunk and suprascapular nerve)

Pt No.	Sex	Age at Op (wks)	Injury	Repair	Postop ROMs (°)		Changes in ROM (°)*	
					Abduction	ER	Abduction	ER
9	F	28.9	C5–6	X1–SSN, C6–UT, C7–UT	180	90	120	80
10	F	29.1	C5–7	X1–SSN, C5–UT	150	95	150	95
11	F	30.0	C5–6	X1–SSN, C5–UT	100	90	60	80
12	M	28.3	C5–6	X1–SSN, C6–SSN, C5–UT, C6–UT	120	45	90	45
13	M	39.7	C5–6	X1–SSN, C7–UT	90	10	45	10
14	F	29.9	C5–7	X1–SSN, C5–SSN, C5–UT	170	90	125	90
15	M	23.1	C5–7	X1–SSN, C5–UT	110	30	20	30
16	F	25.1	C5–6	X1–SSN, C5–UT, C7–UT	150	90	90	80
17	F	25.4	C5–7	X1–SSN, C7–UT	150	90	100	90
18	M	29.0	C5–7	X1–SSN, C7–UT	120	90	90	90

SSN = suprascapular nerve.

* ROM gained after surgery (postoperative minus preoperative ROM).

study of children with OBPI, Tse et al.¹⁸ found no statistical difference in ER ROMs between patients who underwent spinal accessory nerve transfer to the suprascapular nerve and patients who underwent nerve grafting from the proximal C-5 stump. A retrospective study on OBPIs by Seruya et al. compared spinal accessory nerve transfer versus sural nerve grafts for suprascapular nerve repair.¹⁴ They reported a higher median composite Mallet score in their nerve-transfer group (compared to their nerve-graft group) 5 years after surgery; however, the difference did not reach statistical significance (16.0 vs 13.0, respectively, $p = 0.07$).

We hypothesized that the addition of a nerve transfer in this study's dual-nerve-repair group might result in greater shoulder function. We found no difference in shoulder abduction and ER ROMs between patients who underwent single-nerve repair of the upper trunk alone and those who underwent dual-nerve repair of both the upper trunk and the suprascapular nerve. We were unable to find a similar study in the pediatric literature for comparison. Chuang et al.⁵ reported their shoulder abduction results after various nerve-transfer combinations after a minimum of 2 years' follow-up. Their patients' ages ranged from 8 months to 47 years. They reported abduction ROMs after dual-nerve repair of both the suprascapular and axillary nerves that were greater than those after single-nerve repair of the axillary nerve or the suprascapular nerve alone. The mean shoulder abduction ROM after dual-nerve repair was 55°, compared with < 20° after single-nerve repair. They concluded that dual-nerve neurotization provides good shoulder ROM and that neurotization of C-5 is also effective, because it provides axons to the suprascapular and axillary nerves. However, they did not perform nerve repair of C-5 alone to compare with the other surgeries or support their statement.⁵ Terzis and Kosta¹⁷ also found that dual-nerve repair of the suprascapular and axillary nerves yielded improved shoulder results over those with repair of the suprascapular nerve alone; however, their results were not statistically significant.

We acknowledge that our results are subject to the forms of bias associated with retrospective reviews. Although the purpose of our study was to compare functional restoration after single-nerve repair versus that after dual-nerve repair, a potential confounding factor that could not be controlled for is the number of donor nerves involved in the repair. Most repairs involved a single-cable graft; however, dual or even triple grafts were used for more severe injuries, which could represent an example of potential selection bias. Shoulder outcome might be affected by surgical technique (nerve transfer vs nerve graft), which is a variable that could not be accounted for because of the paucity of relevant patients. Potential confounding factors such as frequency, intensity, and compliance with physical/occupational therapy were not accounted for. We also recognize that it is difficult to extrapolate results from a single-center experience. Proof of generalizability of our findings will require external validation by other investigators, preferably with standardized scales of outcome, such as the British Medical Research Council scale. We also acknowledge that our study was underpowered, and larger prospective studies will be required to confirm our findings.

Conclusions

By targeting a single nerve, surgeons have more flexibility and options in treating complex OBPIs with multiple avulsions/ruptures. More options are available for concomitant elbow or hand function repair, which can improve the overall results of the involved upper extremity. Dual-nerve repair of the upper trunk and the suprascapular nerve offers no further benefit than single-nerve repair of the upper trunk alone for shoulder function restoration after OBPIs.

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Disclosures

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

Author Contributions

Conception and design: Azzi, AlNaeem, Kvann, Alam, Zadeh. Acquisition of data: Azzi, AlNaeem, Kvann, Alam, Retrouvey, Aldekhayel. Analysis and interpretation of data: Azzi, AlNaeem, Aubin-Lemay, Zadeh. Drafting the article: Azzi, AlNaeem, Aubin-Lemay, Kvann, Zadeh. Critically revising the article: Azzi, Aubin-Lemay. Reviewed submitted version of manuscript: Azzi, Alam, Zadeh. Approved the final version of the manuscript on behalf of all authors: Azzi. Statistical analysis: Azzi. Administrative/technical/material support: Alam, Retrouvey, Aldekhayel. Study supervision: Zadeh.

Supplementary Information

Previous Presentations

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